(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 March 2002 (21.03.2002)

PCT

(10) International Publication Number
WO 02/23585 A2

(51) International Patent Classification⁷: H01J 37/32

(21) International Application Number: PCT/EP01/10180

(22) International Filing Date: 3 September 2001 (03.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/662,566 15 September 2000 (15.09.2000) US

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(81) Designated States (*national*): JP, KR.

(84) Designated States (*regional*): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/23585 A2

(54) Title: METHOD AND APPARATUS FOR DETECTING LEAKS IN A PLASMA ETCH CHAMBER

(57) Abstract: For use with semiconductor processing, a plasma etch apparatus has a leak detection system in an etch environment. The leak detection comprises monitoring a plasma etch trace. The plasma etch trace exhibits a dip in the plasma intensity. This dip correlates with a change of pressure in the etch environment. In an example embodiment according to the present invention, an etch environment, having an entrance load lock and an exit load lock isolating the etch environment from the atmosphere, is monitored. Leaks in the etch environment to the load locks during wafer transfer and pump down are detected by observing dips in the plasma etch trace.

Method and apparatus for detecting leaks in a plasma etch chamber

FIELD OF INVENTION

The present invention is generally directed to the manufacture of a semiconductor device. In particular, the present invention relates to a process for leak detection in plasma etch apparatus.

BACKGROUND OF INVENTION

The electronics industry continues to rely upon advances in semiconductor technology to realize higher-functioning devices in more compact areas. For many applications, realizing higher-functioning devices requires integrating a large number of electronic devices onto a single silicon wafer. As the number of electronic devices per given area of the silicon wafer increases, the manufacturing process becomes more difficult.

A large variety of semiconductor devices have been manufactured having various applications in numerous disciplines. Such silicon-based semiconductor devices often include metal-oxide-semiconductor (MOS) transistors, such as P-channel MOS (PMOS), N-channel MOS (NMOS) and complementary MOS (CMOS) transistors, bipolar transistors, BiCMOS transistors.

One important step in the manufacturing of such devices is the formation of devices, or portions thereof, using photolithography and etching processes. In photolithography, a wafer substrate is coated with a light-sensitive material called photo-resist. Next, the wafer is exposed to light; the light striking the wafer is passed through a mask plate. This mask plate defines the desired features to be printed on the substrate. After exposure, the resist-coated wafer substrate is developed. The desired features as defined on the mask are retained on the photoresist-coated substrate. Unexposed areas of resist are washed away with a developer. The wafer having the desired features defined is subjected to etching. Depending upon the production process, the etching may either be a wet etch, in which liquid chemicals are used to remove wafer material or a dry etch, in which wafer material is subjected to a radio frequency (RF) induced plasma.

As device geometry approaches the sub-micron realm, wafer fabrication becomes more reliant on plasma etching techniques. In using these techniques, the user

(through his use of etch apparatus) has to provide a stable, accurate, and reproducible etching environment. The variables of vacuum, reactive gas mixtures, RF power, time, and temperature require precise control.

Such control is challenged, if mechanical problems arise in the etch apparatus. One familiar in the art of plasma etching is well aware of the complex electro-mechanical systems present in modern apparatus. To provide the etch environment, the apparatus must not leak. For example, an air leak during wafer etch may result in scrapping of material.

In an effort to avoid leaks, an example standard method of leak detection is carried out in the beginning when machine has just finished its preventive maintenance. The standard method involves venting the load locks and measuring rate of rise of pressure of main chamber after main chamber has been pumped down to a base pressure (vacuum conditions) for prescribed amount of time. During this time, the main chamber is isolated from its pump. The time it takes for the chamber to lose its vacuum is monitored. If the time is too short, there may be a leak.

There exists a need to provide a method of detecting leaks in the plasma etch apparatus so that the user can quickly intervene and perform repairs. Consequently, wafer loss from improper etching is minimized, thereby increasing wafer yields and lowering production costs.

SUMMARY OF INVENTION

The above technique does not check for leaks in real time. During wafer processing, there is no assurance the main chamber does not develop a leak after the initial setup. Techniques that continually monitor the leak integrity of the etch environment are outlined below.

The present invention is exemplified in a number of implementations, two of which are summarized below. According to one embodiment, a plasma etching apparatus has a leak detection system comprising an etching environment with a plasma etch trace monitor configured to sense a dip in the plasma etch trace. The dip in the plasma etch trace correlates to a pressure change in the etch environment. An additional feature of this embodiment is that etch environment may comprise a plurality of chambers. Such a plurality may include a main etch chamber coupled to an entrance load lock chamber and to an exit load lock chamber. The leak detection system senses leaks between the main chamber and the load lock chambers. In another embodiment, a method for detecting a leak in an etch environment during plasma etching of a substrate comprises placing a substrate therein. The

etch environment is pumped down and process gases are introduced. A plasma of process gases is ignited to etch the substrate. The plasma is monitored for any change in the process environment indicating a leak. An additional feature of this embodiment is that the monitoring of the plasma further comprises observing an intensity change of the plasma in an endpoint detector. The intensity change of the plasma sensed by the endpoint detector is correlated to a leak in the process environment. The leak manifests itself as a change in concentration of process gases. The leak may be those elements present in air.

The above summaries of the present invention are not intended to represent each disclosed embodiment, or every aspect, of the present invention. Other aspects and example embodiments are provided in the figures and the detailed description that follows

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. 1 is a top view of an example etch apparatus with the plasma etch trace monitor; and

FIG. 2 depicts a plot of the plasma etch monitor of FIG. 1.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will herein be described in detail.

DETAILED DESCRIPTION

The present invention has been found to be useful and advantageous in connection with semiconductor plasma etching processes. In a plasma etching process it is advantageous to maintain a steady pressure within the etching environment. Before proceeding, the etch environment has to be stabilized. Plasma etching is a well-known technique. For background information, reference is made to Wolf S. and Tauber, R.N. <u>Silicon Processing for the VLSI Era (Vol. 1)</u>. 1986 Lattice Press. Pages 539 – 585 herein incorporated by reference.

It has been observed that a pressure fluctuation in the plasma etch environment, causes a plasma flicker, indicating a leak. Plasma flicker is a visible change in intensity of electro-magnetic radiation emanated by the plasma. A detector is tuned to measure the intensity of a prescribed band of wavelengths. Leaks may often occur at the

door seals of plasma etch apparatus during pump down. They may be caused by broken gaskets, O-rings, missing vacuum grease, and other typical plumbing problems one may encounter in a clean-room wafer fabrication facility.

In an example plasma etch apparatus, a monitoring device in accordance with an embodiment of the present invention, is placed within the main chamber of the apparatus. This apparatus has an entrance chamber called an entrance load lock and an exit chamber called an exit load lock. These load lock chambers isolate the etch chamber from the room atmosphere during loading and unloading of wafers. Contamination control is enhanced in that the load locks help keep the main chamber at vacuum conditions at all times. The load locks receive/transfer wafers to and from the main chamber. In turn they cycle their pressure from atmospheric to vacuum conditions during the process.

Refer to FIG. 1. A chamber 100 is configured with an entrance load lock 110, main chamber 120, and an exit load lock 130. Electronic controls (not illustrated) enable the operator to setup the apparatus for a given etch process recipe. Such controls may be set by the operator via manual controls or be coupled to a computer system or network. A monitor device 140 is placed in the main chamber 120. A wafer substrate 150 is placed into the entrance load lock 110. The load lock 110 is at atmospheric conditions. The load lock 110 then pumps down to about 50 to 100 mTorr so that its pressure is equalized with the main chamber 120 which is at process conditions. Wafer substrate 150 transfers to the main chamber 120 via an entrance door 115. Wafers that have completed processing, exit the main chamber 120 via an exit door 125 to the exit load lock 130. Arrows denote the direction of wafer transfer. While the wafer substrate 150 is in the main chamber 120, the main chamber 120 is pumped down. Load lock 110 is released to atmospheric pressure and another substrate 150 is loaded therein. Having stabilized, the main chamber 120 has its etch process initiated. During etch, the wafer substrate 150 in the load lock 110 is brought down to vacuum conditions. If a leak is present in the load lock 110 or entrance door 115 from the load lock 110 to the main chamber 120, or in the exit door 125 from the main chamber 120 and the load lock 130, there is a pressure change in the main chamber 120. The monitor device 140 senses a change in plasma intensity corresponding to the pressure change in the main chamber 120. The change in plasma intensity manifests itself as short dip (i.e., a flicker) in a plot of plasma intensity v. time in etch.

An example endpoint monitor system uses following approach of detection. Plasma glow from the main chamber is filtered through a prescribed band-filterof wavelengths (through a mono-chromator system). The band is chosen by type of reaction in

the main chamber. The optical signal is converted to an electrical signal and magnified and read by an Op Amp circuit and then sent to analog-to-digital (A/D) converter circuit. Since a signal depends on presence of a type of species in the chamber, its absence at the completion of the process will reduce the signal intensity and hence trigger the end of the process. For example, in a silicon nitride etch, the ionic species monitored include F, CN, and N. The wavelengths monitored are 704, 387, and 674 nm, respectively.

The same endpoint detection system may also be used to tell whether the chamber exhibits a leak during process. Owing to a leak in the chamber, plasma intensity will change. A leak means foreign species, O_2 and N_2 for example, have been introduced into the chamber. The foreign species modify (due to reaction with process gases) the intensity of the wavelengths being monitored. This presents at the detector output as change in intensity that can be used to indicate the leak in the chamber. This change in intensity, if found, occurs at start of pumping cycle of one of the load locks. The presence of leak can be readily detected. Processing is halted and repairs performed. Wafers have not been processed incorrectly.

In an example process according to the present invention, a LAM-ETCHER 4500 is used to detect the leak using its endpoint system. It is useful to discuss what goes on during endpoint detection.

If light comprising all wavelengths (white light) is passed through a prism, the light is broken down into a fairly continuous range of colors from red to violet. The color of greatest intensity is normally dependent only on the temperature of the light source radiating this light. If the light of a low-pressure plasma that contains a single gas is passed through a prism, discrete bands of light will be seen. These bands or spectral lines are unique to each gas species.

In a plasma mixture of gases, the intensity of the spectrum generated by a particular species is dependent on a number of factors including its partial pressure (concentration) and the power applied to generate the plasma. As a particular gas begins to make up an increasing portion of the plasma, the intensity of its spectral lines will also increase. Conversely, as a gas begins to disappear from the plasma, the intensity of its spectral lines will decrease. The endpoint detection method discussed herein makes use of intensity variation due to partial pressure changes (concentration of a gas).

It is not practical to isolate and monitor a single wavelength. Detectors will actually see a range of wavelengths. This range of wavelengths, or bandwidth, is dependent on the methods used for wavelength selection. There are two basic methods available from

Lam for wavelength selection with their own strengths and weaknesses. The standard endpoint detector installed by Lam is an optical photo diode detector. It is cost-effective, easy to use, reliable, and has a high signal to noise ratio. Its weakness is its fairly wide bandwidth. It uses filters that normally have a bandwidth of 10nm (light from 5nm less than the center wavelength to 5nm over will pass through the filter). The optional monochromators can be set to any wavelength between 200 and 900nm with a bandwidth as small as 0.2nm. At high resolutions the amount of light entering the detector can become very small. This then requires a high gain setting that may lead to higher noise levels. Other limitations include high cost, sensitivity to alignment, and lower signal to noise ratio. Consequently, compromises are made between resolution and signal strength.

Refer to FIG. 2. A plot 200 of Trace Counts v. Time depicts a curve 210 exhibiting a plasma flicker 220 owing to a leak in the main chamber 120 and the load lock 110 during pump down. A maximum plasma flicker 220 occurs at the start of pump down of the entrance load lock 110 and the exit load lock 130 during loading and unloading of wafer substrates 150.

Upon observing the plasma flicker 220, steps may be taken to halt the etching process preparation to repair the leaks before any etching takes place. Consequently, the improper etching and resulting scrapping of material is avoided.

While the present invention has been described with reference to several particular example embodiments, those skilled in the art will recognize that many changes may be made thereto without departing from the spirit and scope of the present invention, which is set forth in the following claims.

CLAIMS:

1. A plasma etching apparatus (100) having a leak detection system comprising:

an etch environment (120); and

a plasma etch trace monitor (140) configured to sense a dip in the plasma etch trace correlating to a pressure change in the etch environment.

2. The plasma etching apparatus of claim 1 wherein the etch environment (120) is comprised of a plurality of chambers (110), (130).

3. The plasma etching apparatus of claim 2 wherein the plurality of chambers comprises,

an entrance load lock chamber (110);

a main etch chamber (120); and

an exit load lock chamber (130).

4. The plasma etching apparatus (100) of claim 3,

wherein the plasma etch trace monitor (140) senses leaks between the main etch chamber (120) and the entrance load lock chamber (115).

5. The plasma etching apparatus (100) of claim 3,

wherein the plasma etch trace monitor (140) senses leaks between the main etch chamber and the exit load lock chamber (125).

6. The plasma etching apparatus of claim 1,

wherein the pressure change comprises the entry of non-process gases into the etch environment.

7. The plasma etching apparatus of claim 6,

wherein the entry of non-process gases into the etch environment comprises at least one of the following: oxygen and nitrogen, air.

8. The plasma etching apparatus of claim 1,

wherein the etch trace monitor is an endpoint detector configured to sense an intensity change of the spectral lines of the plasma trace, the change indicating partial pressure changes of a constituent gas in the plasma.

9. The plasma etching apparatus of claim 8,

wherein the partial pressure changes indicate the leakage of non-process gases into the etch environment.

10. The plasma etching apparatus of claim 9,

wherein the non-process gases comprise at least one of the following: oxygen, nitrogen, air.

11. A method (200) detecting a leak in an etch environment during plasma etching of a substrate in an etch environment comprising:

pumping down the etch environment and introducing process gases into the etch environment; and

igniting a plasma of the process gases etching the substrate and monitoring (210) the plasma for a change (220) in the process environment indicating the leak.

12. The method of claim 11,

wherein the monitoring the plasma further comprises observing an intensity change (220) of the plasma in an endpoint detector correlating the intensity change to the leak in the process environment.

13. The method of claim 12,

wherein the endpoint detector is adjusted to sense a change in concentration of the process gases indicating the leak.

14. The method of claim 13,

wherein the change in concentration of process gases comprises the introduction of at least one of the following: oxygen, nitrogen, air.

15. The method of claim 14,

wherein the etch environment is a plurality of chambers comprising,

an entrance load lock chamber;

a main etch chamber; and

an exit load lock chamber.

16. The method of claim 15,

wherein the endpoint detector detects a leak from the main chamber to at least one of the following: the entrance load lock, the exit load lock.

17. The method of claim 16,

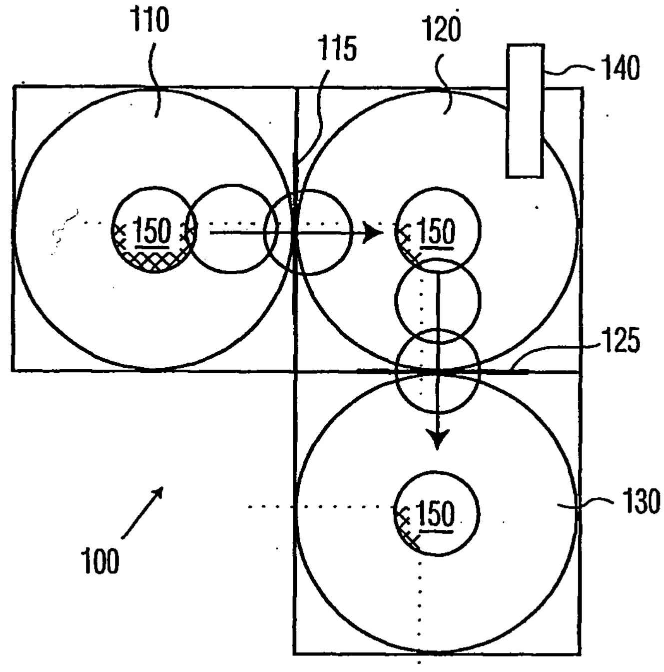
wherein the endpoint detector is adjusted to sense a change in concentration of the process gases from the leak of ambient atmosphere in a wafer production environment.

18. The method of claim 17,

wherein the endpoint detector detects a gas from the ambient atmosphere from at least one of the following: air, nitrogen, oxygen.

19. A semiconductor device manufactured by the method of claim 11.

20. A semiconductor device manufactured in an apparatus as recited in claim 1.


110
115
120
140
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150
125
150
130
100

FIG. 1

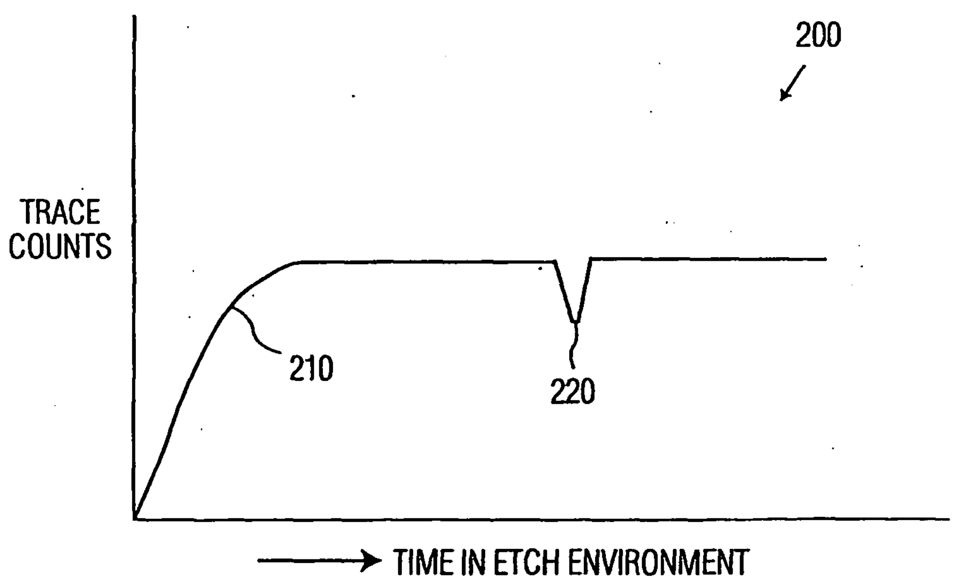
200
TRACE COUNTS
210
220
TIME IN ETCH ENVIRONMENT

FIG. 2